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Mandala Generation from Brainwave with Feedforward

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Mandala Generation from Brainwave with Feedforward

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Abstract

Most experiments conducted in the early 1900s with Electroencephalography (EEG) [10] devices explored mental illness of the participants. Historically, EEG has had specific applications to diagnose sleep disorder, epilepsy, coma and brain death. Today, EEG devices are used extensively for research purposes [10], especially in the field of neuroscience. Traditionally, most experiments included a human participant wherein an EEG device was connected to the subject's forehead to detect electrical impulses indicating different brainwaves. Each brainwave implied a different emotional state of mind. Past experiments [2] [3] [4] then used the brainwave signals as input to build audio/visual art to aid in the analysis of mental health to some degree. However, the full potential to develop cheap real-time monitoring systems with novel hardware has not yet been exploited. This report attempts to bridge that gap by discussing a new feed-forward system for meditation that is built upon dynamic mandalas, controlled by brain waves. A relatively recent brainwave intercepting device, Muse™, is used to collect α, β, and γ brainwave signal data from human subjects in short sessions. The data is collected in both, feedforward as well as feedback usage scenarios. Exploratory analysis of the collected data indicates that majority of the participants had a calming and relaxing experience upon using Muse and the dynamic Mandala generation system.

Index terms - Electroencephalogram (EEG), mandala, neuroscience, processing, meditation

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CHAPTER ONE

Background

1.1 Introduction

Many scientists in the past have been attracted to the idea of understanding human brains. Carl Jung [1], an influential psychiatrist, did experiments on symbolism and psychology. During his experiments, he documented handwritten notes and illustrations. Jung's illustrations were very rich, precise and had a strong resemblance to Tibetan art form, the mandala. He concluded that as a psychological phenomenon, mandalas appear often in our dreams in cases of conflicts or schizophrenia. Soon, there was a focus on experimenting with Jung's theory of connection between psychology and mandalas.

To understand the meaning of a mandala, we first need to understand the origin of mandalas. Mandala, a circular art made up of various patterns, is a very important and significant tradition in Buddhism. A group of monks apply precise mathematical techniques to create a mandala that takes about a week to be completed. The whole ceremony involves a lot of chanting and rituals. Mandalas hold religious and psychological meaning in Tibet. Both Jung's theory and Tibetan Buddhist philosophy [7] agree on the goal of going through a transformation only to find Self, Buddhahood or Wholeness, and visual representation of self is the center nucleus or the heart of a mandala.

1.2 Mandala and Psychology

Tibetan Buddhism has many visually rich traditional rituals [7]. Mandala is a culture in Tibet. Colorful sand is used to create mandalas. In Tibetan temples [5], a group of monks will perform the ceremony before the creation of the mandala, which is dismantled after its completion. This ritual demonstrates Buddhist belief of following the path of non-attachment to earthy material. Mandala works as support for meditation and finding the true purpose of life. Mandala is a combination of our outer (the universe) and inner (mind) cosmos as well as the relation between them. Fig. 1 shows monks in the process of making a mandala in a Tibetan temple [8]. Four monks work in unison to build four precisely similar corners of one big mandala as a part of their ritual. A mandala represents the blueprint of one's own mental transformation.

Fig. 1. Four monks working on their own different quarters of the mandala in Tibetan temple

1.3 Different Modality of Meditation and Meaning

There are a few different ranges of brain waves that an EEG device detects. We will focus mainly on three brain waves - Theta (4-7 Hz), Alpha (7-14 Hz) and Beta (14-30Hz). Theta brainwaves represent a calm and peaceful state of mind. Alpha brainwaves represent a relaxed and learning state of mind. Beta brainwaves represent an agitated state of mind. Fig. 2 shows different frequency brain waves, its behavioral understanding and their implication on different states of mind [2].

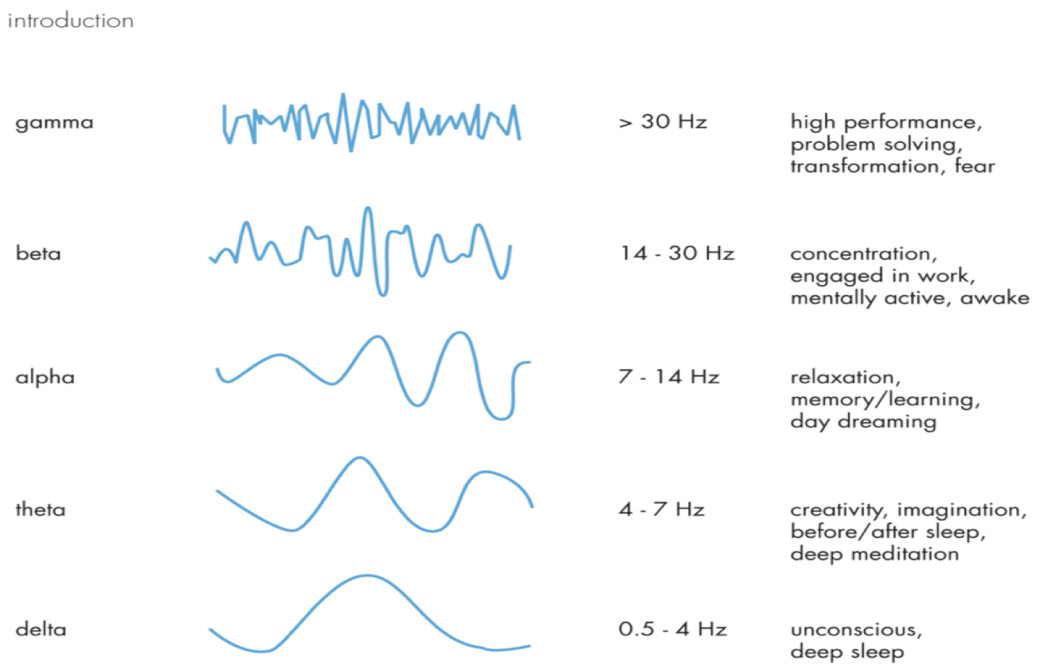

Fig. 2. A chart of brainwaves, its frequency, and behavior

There are few different ways to extract and construct feedback signals from human brainwaves. Tokunaga and Lyons [4] conducted an experiment called Enactive Mandala to explore artificial expression and audio-visual representation of real-time psychological data. This experiment is a real-time audiovisual feedback system of EEG signals. It maps real-time EEG signals to modulate music and animated visual music.

Vladimir Gontar [3] approached this problem differently compared to Enactive Mandalas. He explored Jung's theory [1] of the healing power of the psychological phenomenon of mandala images. He mapped real-time brain signals to a function to generate visual mandalas. Baasanjav's [2] approach to Jung's theory was similar to Gontar's, but with a different mapping system. He directly mapped all brainwave signals to a fixed color. This constant was determined after considerable research on colors and human visual perception.

A typical installation for these feedback-system experiments consists of a feedback outlet, an EEG device, and a participant. Fig. 3 shows one such experiment done by Baasanjav's installation [2] for feedback via brain waves. A participant is connected to an EEG device band. A computer system then listens to signals from the EEG device via Bluetooth. With the help of a look-up based mapping or a transformation algorithm, these brain waves are converted to audio/visual form. When a participant observes the feedback from brainwaves, he/she can assess how stressed or focused or calm he/she is feeling. This could also be looked at as a unique form of art since every participant builds his/her own unique visual imagery.

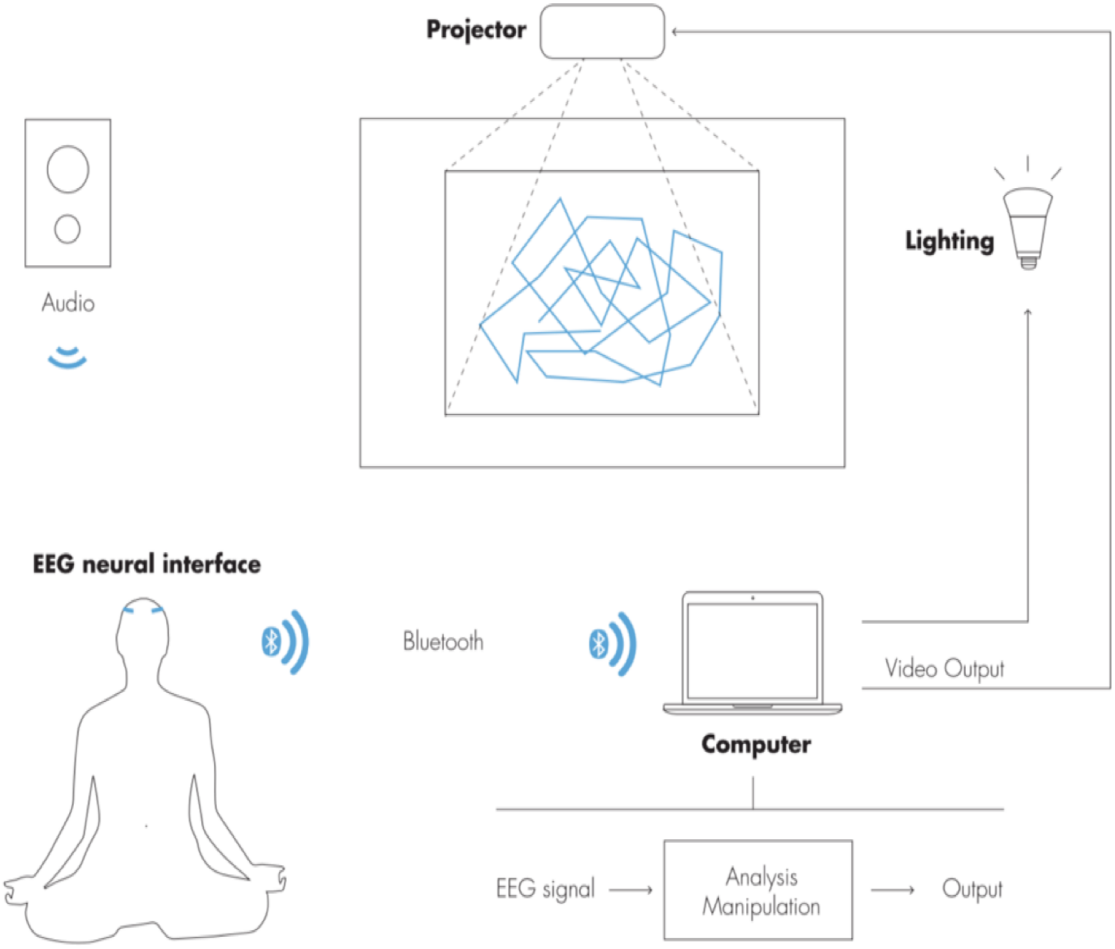

Fig. 3. An illustration of the installation for the feedback system

Fig. 4 shows the breakdown of the installation problem [2] of all the aforementioned experiments. The *design aspect* is a mapping algorithm for audio or visual output, *tech aspect* is an EEG device, a computing system, and a projector and *human aspect* is participants who are trying the installation.

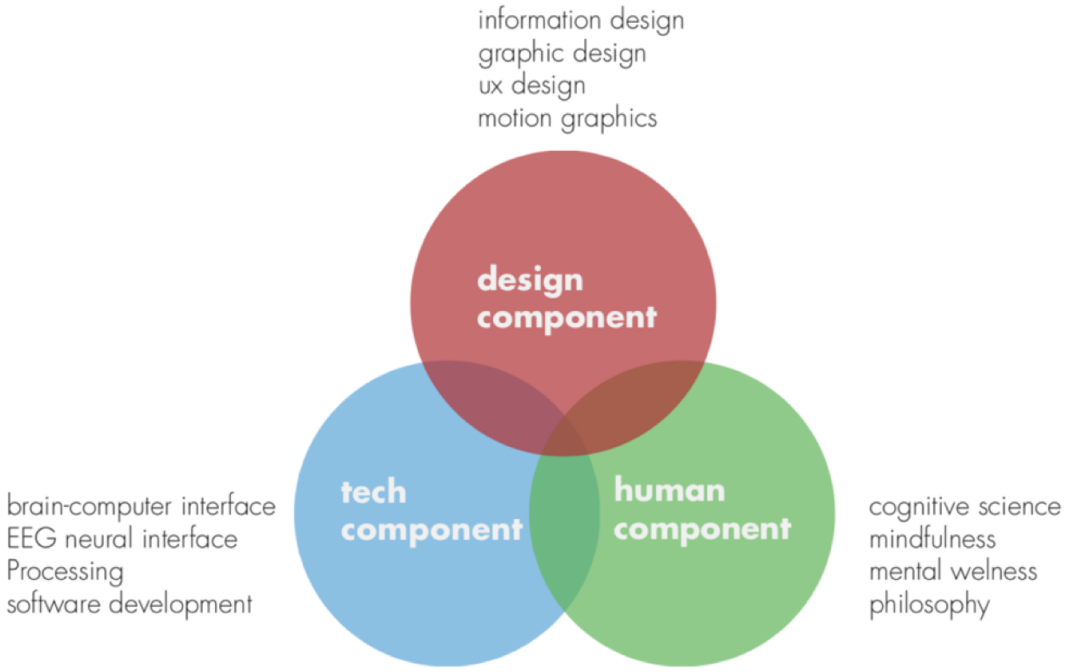

Fig. 4. Three areas of implementation of the feedback system

Compared to other areas of neuroscience, EEG signal feedback systems still need further exploration and enhancements. Jung's theory [1] of the healing power of mandalas on our psychic wholeness remains a fertile area of research, and is still a major motivation behind most brainwave feedback experiments. However, this still leaves a vast area of feedforward systems unexplored. For example, an enhanced system would not only work with mapping brainwaves to colors and patterns but would also build upon the input signal to create an intelligent system. Based on a feedforward approach, such an improved system would require minimum supervision and would help participant self-meditate.

A feedforward approach is based on prediction of those elements that helps the participant in attaining a calmer state of mind. Furthermore, these predicted elements could be used to drive the mandala generation process for better self-meditation. Section 2.3.2 discusses feedforward approach to a mandala generation.

1.4 Introduction to Muse (EEG Device)

Muse is a brainwave sensing EEG device used for meditation purposes. Muse headband gives accurate, real-time feedback on what's happening in the brain when one meditates. Muse has a total of four sensing plates. Two of the sensors attach to participant's temple and the other two are attached behind both the ears. Fig. 5 shows a Muse [6] device and explains the key elements. Fig. 6 shows the placement of Muse [6] on a participant's forehead.

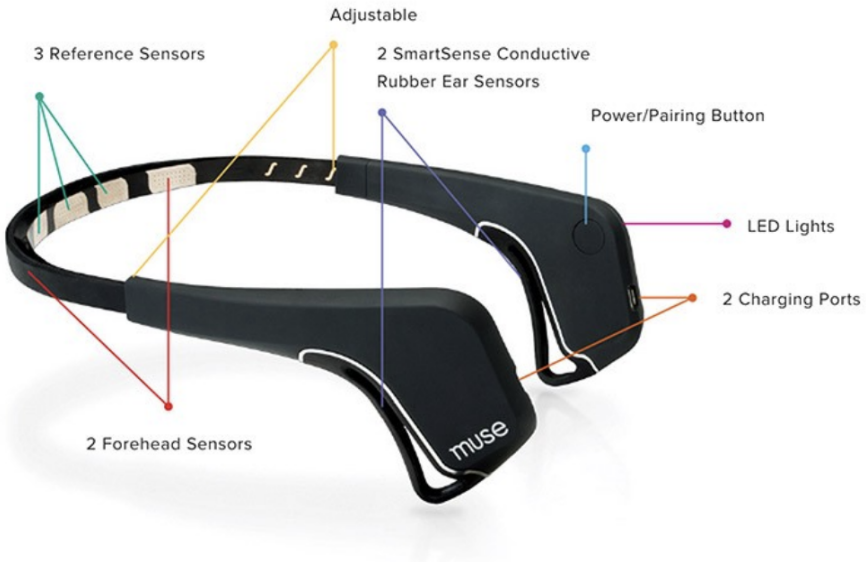

Fig. 5. Information on Muse (EEG device)

Fig. 6. Placement of Muse on a participant's forehead

1.5 Processing Software Tool

To create mandala sketches, we will use the *Processing* environment. Fig.7 shows the software components required to generate mandalas [2] from brainwaves. *Processing* [11] is a flexible software sketchbook. We communicate data from an EEG device to the *Processing* platform via an oscP5 library. The data stream is in the decimal format. Among the brain waves detected in different frequencies, we focus on three – α, β, and γ waves. The brainwave that's most prominent in each cycle is selected and used as an input that decides the primary mandala structure.

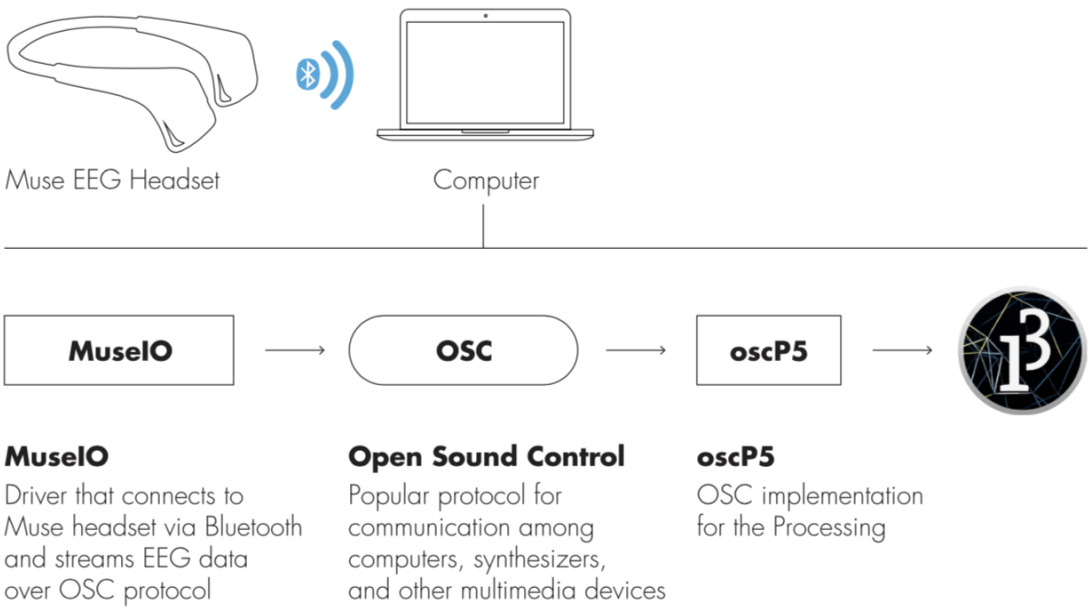

Fig. 7. Software components required to connect brainwaves to mandalas

CHAPTER TWO

Methods

2.1 EEG Device Setup

We start by connecting an EEG device to a computing device's operating system (OS) via Bluetooth. Fig. 8 shows the simple pairing of EEG device to the OS. Next, we download and install *MuseIO* from Muse forum [12] for this experiment. To connect *MuseIO* with a Muse device, the following command is executed on a Bash shell:

```
muse-io --device MUSE_DEVICE_NAME
```

MuseIO is thus connected to Muse and then sends out OSC messages containing Muse data to the default TCP port 5000. Fig. 9 shows the connection of *MuseIO* to Muse via TCP port 5002. The next step involves analyzing the OSC messages to generate mandalas.

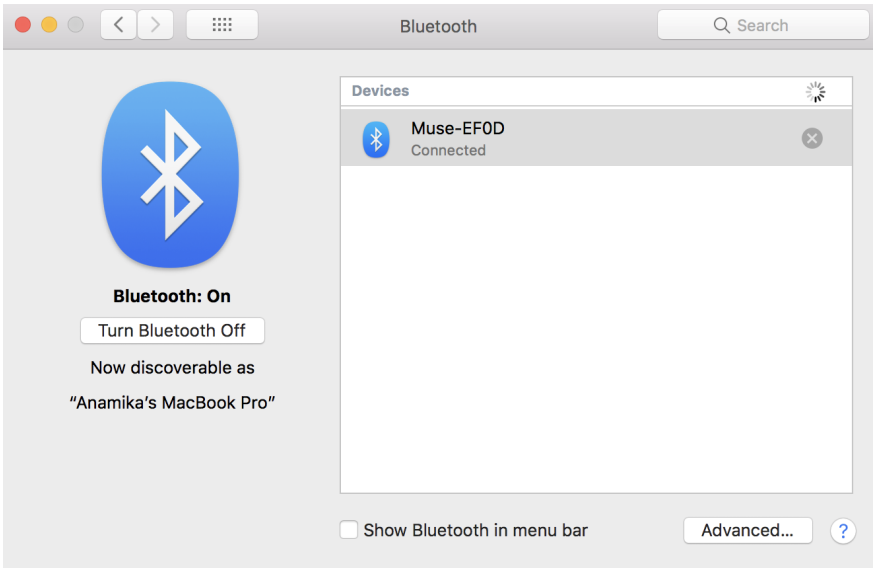

Fig. 8. Connecting EEG device to the operating system

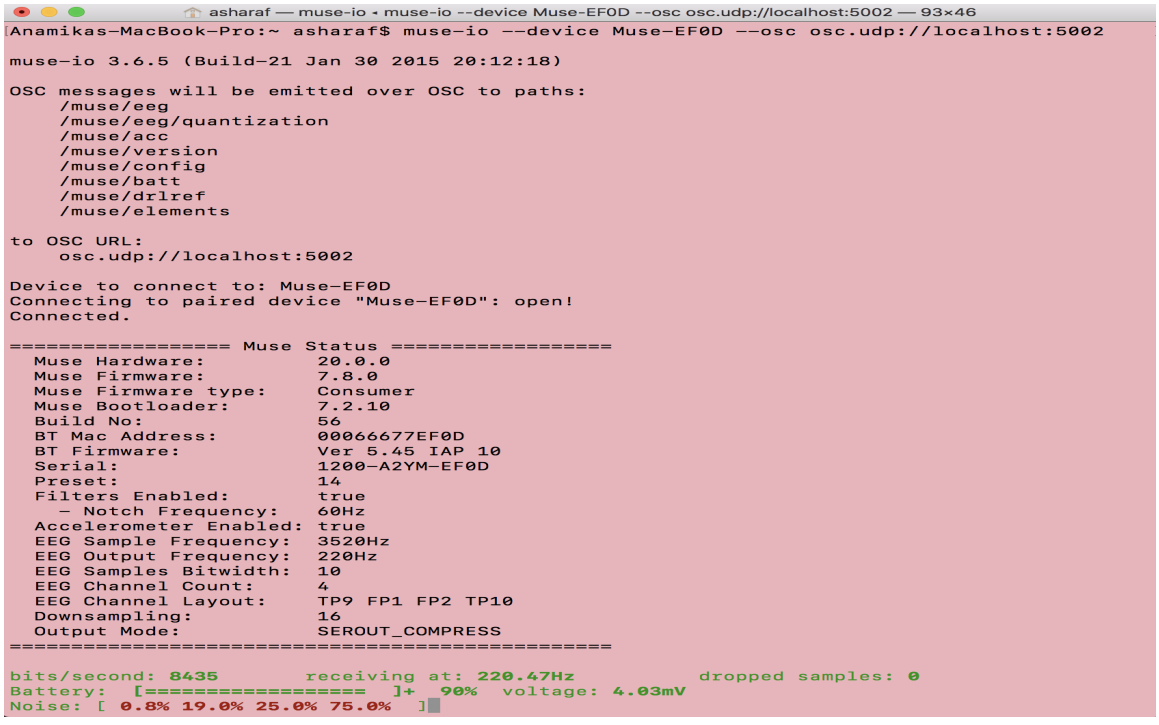

Fig. 9. Connecting MuseIO to Muse device via TCP port 5002

2.2 Analyzing OSC messages to generate Mandalas

We use the *Processing* platform to build an interactive visualization. To connect to OSC data, we need to import oscP5 library. Fig. 10 shows a sample OSC event for listening to OSC data [6].

```
import oscP5.*;

// OSC PARAMETERS & PORTS
int recvPort = 5000;
OscP5 oscP5;

// DISPLAY PARAMETERS
int WIDTH = 100;
int HEIGHT = 100;

void setup() {
  size(WIDTH,HEIGHT);
  frameRate(60);

  /* start oscP5, listening for incoming messages at recvPort */
  oscP5 = new OscP5(this, recvPort);
  background(0);
}

void draw() {
  background(0);
}

void oscEvent(OscMessage msg) {
      System.out.println("### got a message " + msg);
      if (msg.checkAddrPattern("/muse/eeg")==true) {
              for(int i = 0; i < 4; i++) {
                      System.out.print("EEG on channel " + i + ": " + msg.get(i).floatValue() + "\n");
              }
      }
}
```

Fig. 10. A sample code to listen to OSC data through Processing platform

After the connection is established, we start using this data to build mandalas. As mentioned earlier, the emphasis is on three important signals: Theta (4-7 Hz), Alpha (7-14 Hz) and Beta (14-30 Hz) brain waves.

2.3 Mandala Generation

To create mandalas from OSC data we need to focus on few important points. First, which aspect of mandalas should be altered by the incoming data? Second, how should we map the shapes of mandalas to brainwaves? Based on ideas discussed in [9] this report makes the following assumptions: (a) Sharper mandala shapes map to the most agitated state of mind and rounder shapes to the most relaxed state of mind. To tackle the intermediary states, we use shapes such as square or rectangle. (b) Although, this system will not be mapped based on colors, the selection of colors used to create mandalas are very meaningful to mandala ritual. The basic colors are red, green, blue and yellow. Each of these colors has a dark and a light shade. We incorporate not only a feedback system but also build a feedforward system to further help the participant to get maximum benefit from this experiment. The feedforward system is discussed in section 2.3.2.

2.3.1 Mandalas via Feedback

To generate mandalas via feedback system, we map the shapes of the mandalas to the intensity of the brain waves detected. For Beta brainwave, the emphasis is on sharper shapes, such as lines or triangles of different dimensions. For Alpha brainwave, square or rectangles with rounded edges are considered. For Theta brainwave, circles of different radii are used. The dimension of the shapes is picked up randomly. We experiment with the intensity of the shapes to give it a faded effect. At the beginning of a session, we seed the input file with customized data (length of session, feedforward or feedback mode, etc.) for each individual participant. This feature makes

the meditation personalized for each participant. Fig. 11 shows a sample input file for the feedback system. Fig. 12 and Fig. 13 show few sample feedback mandalas. At the end of the session, we collect a resultant output file that contains all the data related to the session. The data collected during the session could be extremely useful to the participant to ponder upon what worked while meditating. Fig. 14 shows a sample output file for a feedback meditation session.

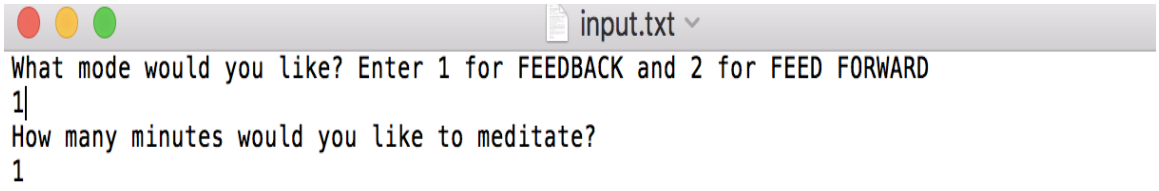

Fig. 11. A sample input file for a Feedback system

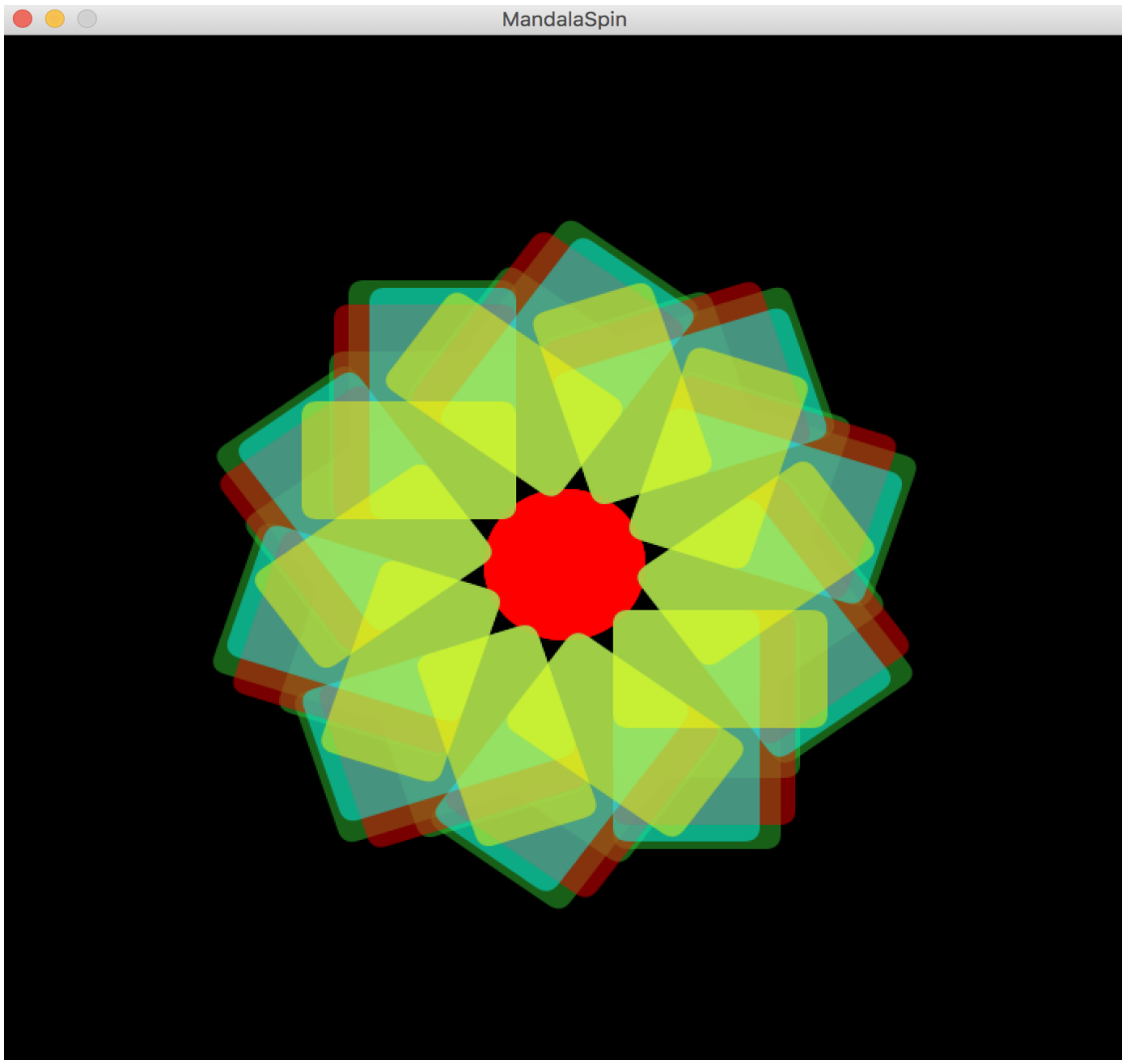

Fig. 12. Mandala Sample 1 - Feedback System

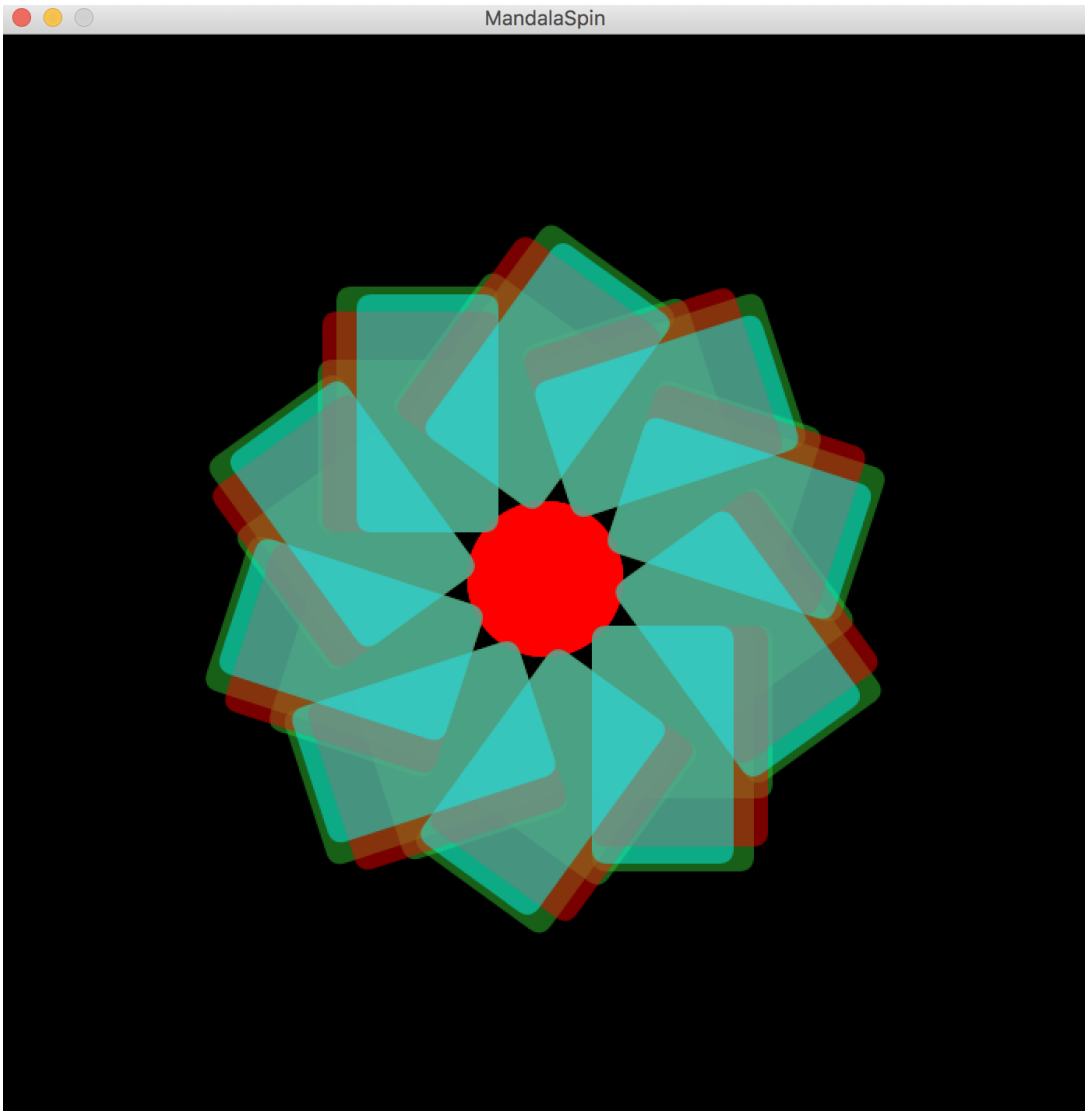

Fig. 13. Mandala Sample 2 - Feedback System

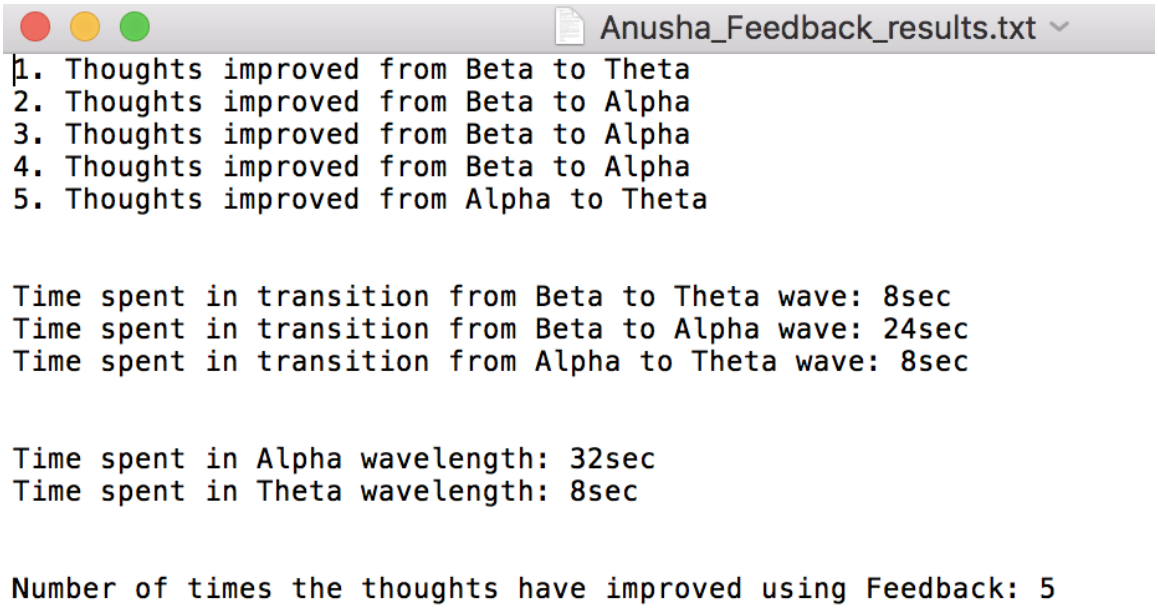

Fig. 14. A sample output file for a Feedback system

2.3.2 Mandalas via Feedforward

The idea behind feedforward system is to generate mandalas not only to assess the brain waves but to use this opportunity to help the participant attain a calmer state of mind. The feedforward system detects the colors that worked for the participant in improving their brainwaves. Next, the algorithm uses those detected colors to build mandalas for a desired calmer state of mind. The choice of color is fully automated and adaptive. Helpful color in each cycle is detected and persisted. If it's detected that a color is no longer helpful, a different color is randomly selected by the algorithm. The color selection is a dynamic process and continues till the participant has attained a calmer state of mind.

Without having any dependency on one color, feedforward system constantly looks for color that works for the participant for that particular moment. Fig. 15 will show a sample input file for feedforward system. Fig. 16 and Fig. 17 show few sample mandalas for feedforward system. Fig. 18 shows a sample output file for feedforward system.

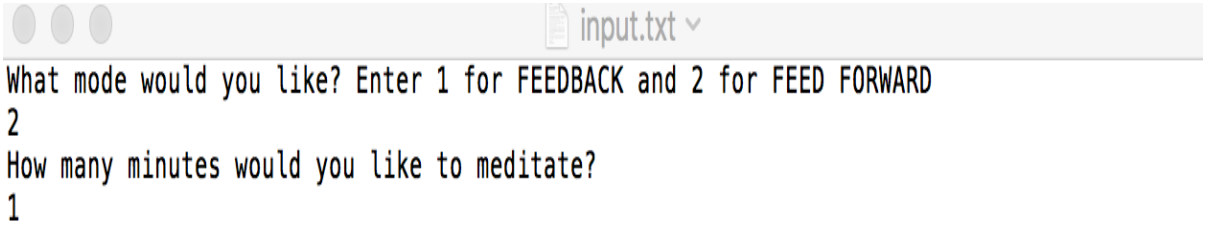

Fig. 15. A sample input file for a Feedforward system

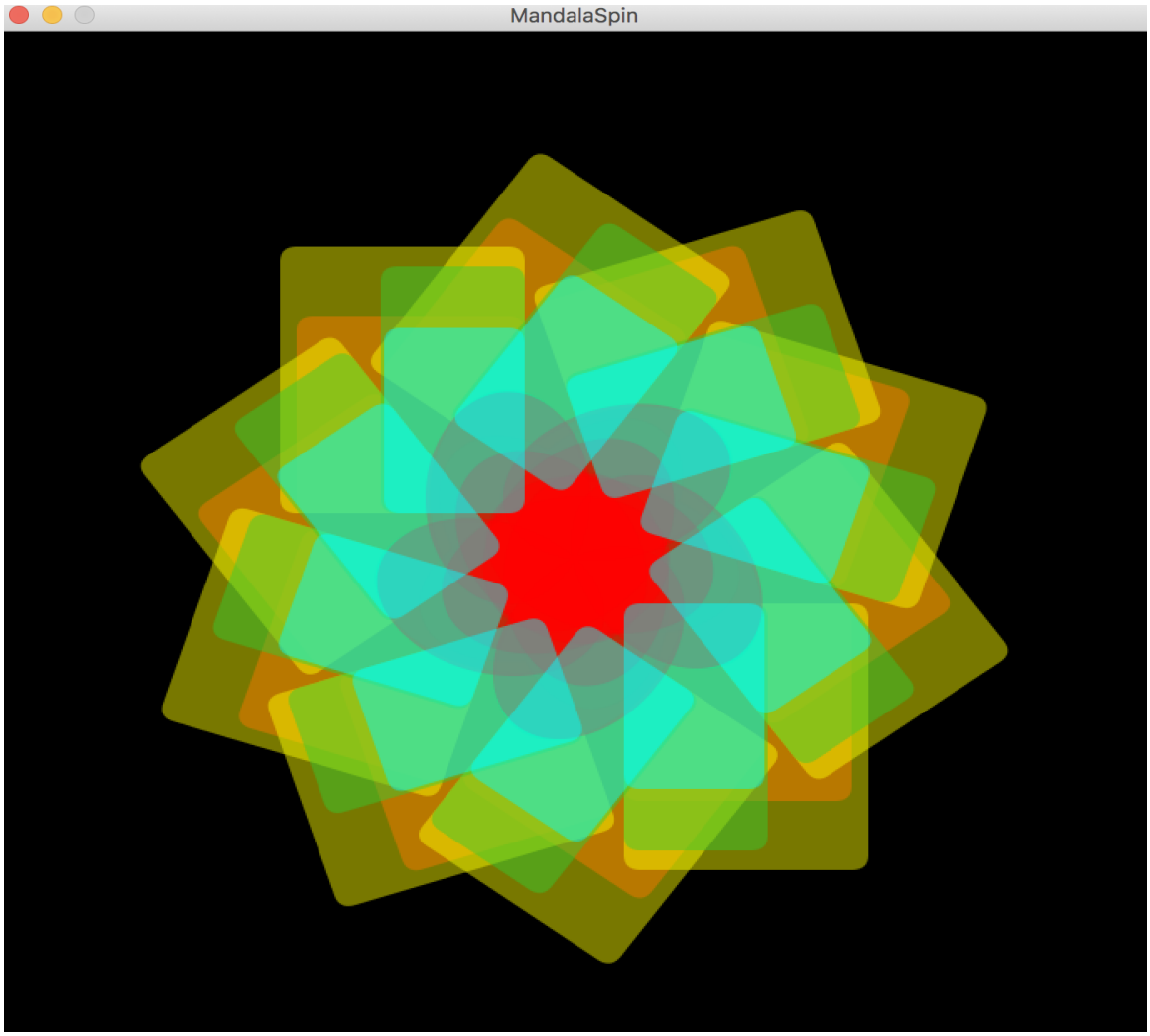

Fig. 16. Mandala Sample1 - Feedforward System

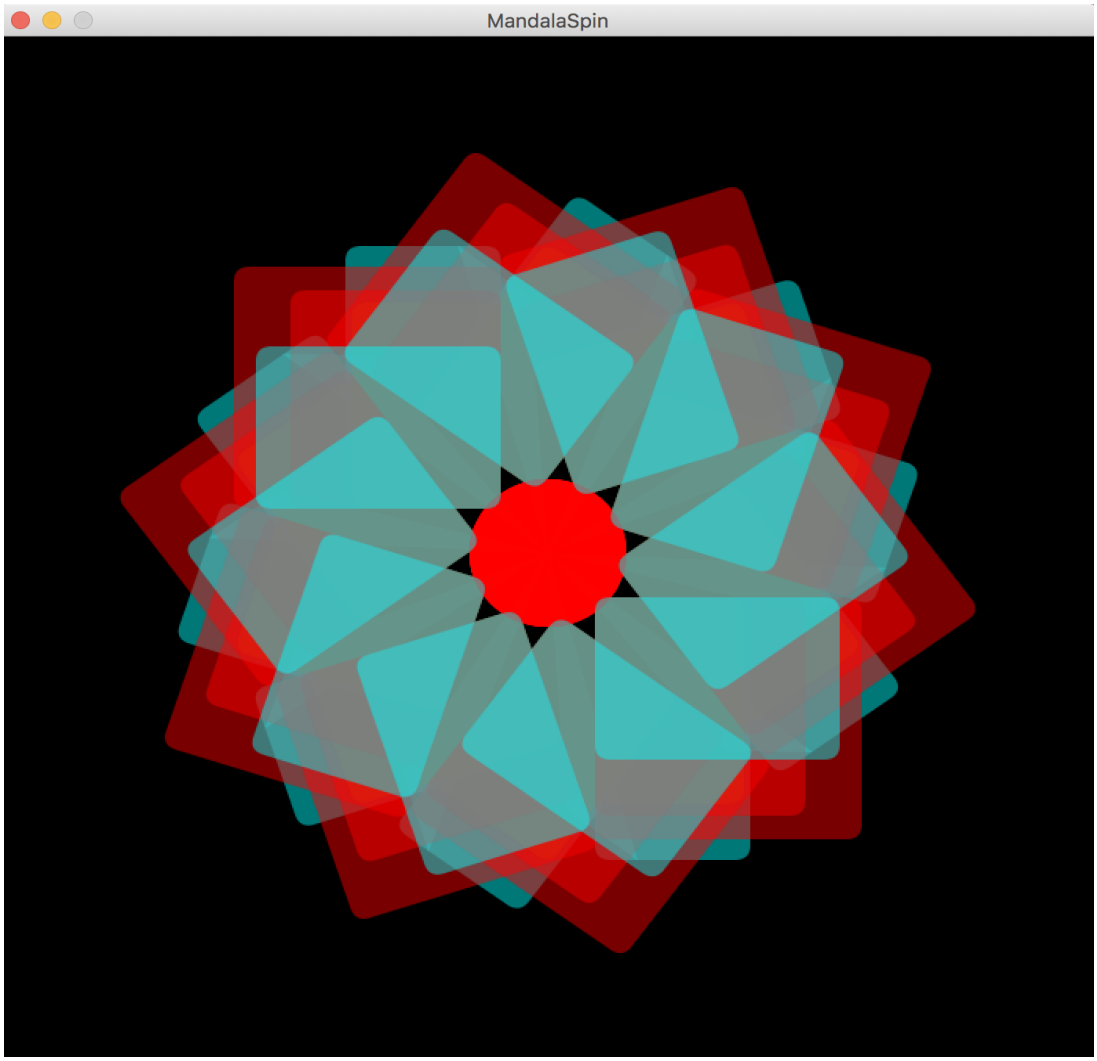

Fig. 17. Mandala Sample2 - Feedforward System

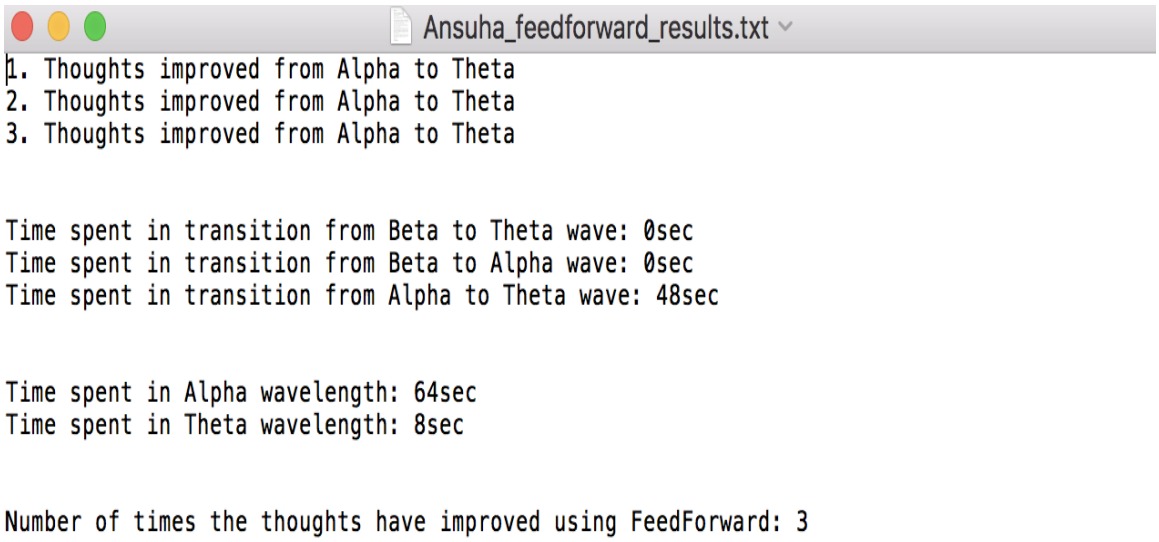

Fig. 18. A sample output file for a Feedforward system

2.4 Participant's Feedback

We asked few people with different occupations and different interest in meditation to try out these systems. Twenty volunteers sequentially tried a feedback system, followed by a feedforward system. Each session was held for 2 mins. Participants then filled in a feedback form (Fig. 19). Next, we generated mean and standard deviation parameters from the collected data to evaluate which system worked better for the majority of the participants.

Feedback Form for Mandala Generation

Name:
Occupation:

1. **Do you meditate regularly?**

2. **How effective was the feedback experience at inducing a relaxed state? (Not effective, slightly effective, moderately effective, extremely effective)**

3. **How effective was the feedforward experience at inducing a relaxed state? (Not effective, slightly effective, moderately effective, extremely effective)**

4. **Which experience did you prefer (feedback, feed forward, neither)**

Fig. 19. Feedback form for all participants to fill after their session

CHAPTER THREE

Results

Fig 20 shows the data collected from all the participants. The calculated mean for the effectiveness of feedback system (column 4) is 1.6 and effectiveness of feedforward system (column 5) is 2.2 whereas standard deviation for the same dataset for feedback system is 0.82 and feedforward system is 0.69. The interpreting scale is discussed in chapter 4.

Participant #	Occupation	Do you meditate regularly?	How effective is feedback system?	How effective is feedforward system?	Feedforward - Feedback	Which experience do you prefer?
1	Student	No	1	2	1	feedforward
2	Student	No	2	2	0	feedforward
3	Student	No	2	2	0	feedforward
4	Student/ App Engineer	No	1	1	0	feedforward
5	Student	No	1	3	2	feedforward
6	Student/ Realtor	No	2	3	1	feedforward
7	Student	No	2	3	1	feedforward
8	Student	Semi-Regularly	1	2	1	feedforward

9	Student	No	1	2	1	feedforward
10	Student	No	1	2	1	feedforward
11	Student/Intern	No	1	1	0	feedforward
12	Student	Yes	3	2	-1	feedforward
13	Admin Analyst	No	3	3	0	feedforward
14	Student/ Software Engineer	No	1	2	1	feedforward
15	Student	No	0	2	2	feedforward
16	Professor	Yes	2	3	1	feedforward
17	Student	No	2	3	1	feedforward
18	Software Engineer	No	2	3	1	feedforward
19	Software Engineer	Semi-Regularly	3	2	-1	feedforward
20	Home-Maker	No	1	1	0	feedback

Fig. 20. Data collected from all feedback forms

CHAPTER FOUR

Discussion

From Fig. 19, it's quite clear that nineteen out of twenty participants preferred the feedforward experience over feedback experience (column 7). Most volunteers admitted benefiting from feedforward system's assistance. Analyzing the table further, we can say that even for volunteers with no experience in meditation, using both, the feedback and the feedforward system, was a calming and helpful experience. For participants with a considerable amount of meditation practice, this system helped them to be better at meditation. The mapping of the effectiveness of these systems is shown in Fig. 21.

Effectiveness	Points
Not Effective	0
Slightly Effective	1
Moderately Effective	2
Extremely Effective	3

Fig. 21. Mapping effectiveness to numbers

The effectiveness scale is shown in Fig. 21 goes from 0 to 3. Zero being least effective and three being most effective. Clearly, feedforward system is preferred over feedback system.

The goal of this experiment was to figure out a system that could bridge the gap we had discovered in earlier attempts, as discussed in section 1.3. This report proves that a better mapping system can to be developed that works well, combining the psychological meaning behind colors and patterns with the signals generated by a human brain. In a nutshell, we developed a system that stands out as a novel approach, compared to the rest of the meditative methods available in this field. We not only mapped the brainwaves to generate beautiful mandalas but also figured out a new feedforward system that uses participant's preferred calming colors, *in situ* in a session, to make meditation even more effective.

CHAPTER FIVE

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